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Launch Team Training System

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LAUNCH TEAM TRAINING SYSTEM

BY

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ABSTRACT

A new approach to Shuttle Launch Team Training is required. This change is driven by two major factors; i.e., adjustment of training philosophy from a short term RVD effort to a long term program, and a consideration for the transfer of knowledge from long term professionals to neophytes entering the program. To be cost effective, it is necessary for this approach to build upon and enhance presently utilized training techniques. Three different companies have been contracted to study the Shuttle Processing Contractor's (SPC) current training methodology and equipment, and then subsequently recommend changes and new approaches for the Launch Team Training System of the future. The Launch Team Training System (LTTTS), as presently envisioned, will combine management action, hardware, software and communications networking into a structural system which will be utilized to train, certify, recertify and maintain the proficiency of the KSC Launch Team, both individually and in groups.

INTRODUCTION

The primary purpose of the SPC KSC NASA/Contractor Team is to assemble and verify the proper functions of hardware/software systems and to safely launch the integrated package

into orbit. In order to accomplish this primary mission, both NASA and contractor personnel are required to be highly skilled and very competent in all the individual tasks that each are required to accomplish. This paper provides an overview of the training techniques that the KSC NASA/Contractors have used in the past, what they are doing today, and where they must go in the future to ensure successful accomplishment of the primary mission: "to test and launch Shuttles and their Payloads into orbit".

PAST

We need to examine how and why we did things in the past to better understand how and where we should go in the future. This holds true for designing both training and hardware systems - Form Follows Functions -.

Historically, here at KSC, contractors have been faced with relatively short duration programs: Mercury lasted 3 years, Gemini lasted almost 2 years, and Apollo lasted nearly 6 years. Training and information knowledge was usually gained by individual involvement in the Vehicle or GSE design, development of check-out procedures and on-the-job training. The work force, once trained, generally stayed with the program. During these short programs, personnel attrition and the requisite

training required, was not a consideration of any great magnitude. When an existing program had a change of prime contractors, a good portion of the incumbent work force was employed by the winning contractor, which effectively transferred their experience. The glue that held it all together and provided continuity was the NASA work force. However, at the conclusion of Apollo Soyuz the contractor work force was scattered and NASA personnel were diverted into different areas.

The beginning of the Shuttle program saw the gathering of the remnants of the various contractor Apollo Test Teams. NASA provided much of the technical expertise, while the contractor teams learned from NASA's experience base. During the start-up phase, training of personnel took the classical KSC approach - learn by doing. Thus during the first few flights, the Test Team developed its expertise by working together, learning from its mistakes and troubleshooting the many component failures always present in a new state of the art program. A total Test Team dress rehearsal for Launch was accomplished utilizing the flight hardware during a Terminal Countdown Demonstration. Limited malfunctions were induced during this test to exercise the Test Team. Because of Vehicle configuration, the type and fidelity of the malfunctions were heavily restricted.

Training of the Test and Launch Team during these first 11 flights was accomplished by a combination of formal classroom courses taught by professional instructors or taught by engineers proficient in the required skill or system, and on-the-job training (OJT) as determined by supervision. Emphasis was placed on OJT to hone the skill level of the individual. Actual testing of the flight hardware maintained that skill level.

For the first time in KSC processing history, issuance of the Shuttle Processing Contract (SPC) presented a contractor organization with a long duration program (possibly 15 years) that would require planned replacement and training of its work force. In addition, the processing rate required by the projected manifest precluded the ability to learn by doing. There was also a shifted emphasis to a Load & Launch philosophy. As the program matured, component failures were reduced, so the opportunity to train by troubleshooting actual hardware failures declined considerably.

Figure 1 shows that processing time has declined as the program matured. Note that in most cases, long processing time is associated with first flow vehicles.

PERSONNEL

The SPC is responsible for all KSC related activities involving the Shuttle in the National Space Transportation System. A major contractual obligation is to have in place a skilled, motivated, trained, proficient and certified Launch Team, capable of the safe and efficient checkout and launch of the Space Shuttle. To meet this obligation, all employees involved in the processing activities must be trained, tested, certified and periodically recertified to ensure that operations and hardware testing are performed in compliance with acceptable standard practices. Determination of the best way to accomplish this task while still processing Shuttles is a major goal which has yet to be accomplished.

An analysis of program training needs indicates that required Test Team knowledge can be classified into three broad areas: policies & proce-

dures, skills, and technical knowledge of Shuttle systems. Policies & procedures apply to all the processing work force, skills apply mostly to the Technician and Quality Assurance personnel, and Shuttle systems expertise applies mainly to the Process Engineering (console operators) work force.

The core of experienced personnel, both NASA and contractors, is aging. Many of the experienced people have moved into management positions and out of the hands-on work force. Many inexperienced engineering personnel have entered the work force (today approximately 25% of the Process Engineers have less than one year experience in Shuttle checkout). The time to adequately train and certify engineering personnel can vary from 12 to 18 months. Considering these facts, it became apparent that improved methods of training and experience transfer were necessary.

The question of how to transfer the operational knowledge from the existing experts to the new kids on the block had to be answered.

The SPC instituted a two pronged approach to solve the training problem. The first thrust was short range to take care of immediate training requirements by the expansion of the current training methods, improvement of existing simulation capability, and the scheduling of training exercises with the same priority as hardware tests. The second thrust was the study of the whole SPC Training program, and the development of user requirements which would take advantage of state of the art tools and techniques used by others outside the KSC environment.

To accomplish the short range goal, the SPC undertook the task of identifying and formally documenting training requirements for all personnel requiring certification. This

task has generally been accomplished; however, fine tuning and standardization of requirements is still underway. In addition, a team of Engineers and Operations personnel was tasked to expand and enhance the simulation capability using the hardware and software inherited by the SPC. The fidelity of math models developed to support application program validation for the 27 major Shuttle systems were modified from low fidelity (capable of local ramping of analog processes) to high fidelity (which actually reflects hardware activity and effects resulting from any stimulus, normal or abnormal). Further enhancements included intercommunication between system models which were once stand alone. Integration of system models necessary to support a typical Launch scenario have been developed and implemented. This integration requirement gave rise to radical changes in existing models in order to streamline execution times and reduce the total computer execution requirements. These changes were necessary to minimize the actual lag from real time under heavy execution periods and to allow for large master models to be utilized. An additional need for the model to recycle to nominal pre-configurations upon a user's request was also identified and partially accomplished. The Countdown can now be recycled to a T-20 Minute configuration.

To give some idea of the size of the current simulation, there are 94,500 model statements and 86,700 model control procedure statements that have been developed, debugged and implemented.

Currently, the Launch Team is participating monthly in three Launch Countdown Simulations (from 20 minutes prior to Launch) with inserted malfunctions. Since the initiation of these exercises in Feb. of 1987, the models have been improved such that

the lag in execution from real time has gone from formerly as much as 30 seconds behind to now only 2 or 3 seconds behind at T-0.

Although the present simulation capability is considered highly successful, it became apparent that additional enhancements to the simulation capability are severely limited by the existing hardware and software, as evidenced by:

a. Excessive time required to design and build Model Control Procedures (MCP) so they can be executed in the allotted 8K execution space.

b. Excessive time spent optimizing model execution efficiency to maximize usage of the limited Central Data System (CDS) resources.

c. Excessive time utilized minimizing model table space usage to conserve the CDS resources.

d. Lack of computer speed to simulate wave functions, sample rates real time outputs and solutions to systems of partial differential equations.

e. Lack of ability to effectively simulate meters/talkbacks, switch and circuit breaker positions, failed cells and model variables for both flight hardware systems and GSR.

f. Excessive time required to initialize the simulation system. It presently takes four hours to set up and initialize the models.

g. Inability to stop the simulation, rapidly reset the models back to some predetermined point, or jump ahead to some predetermined point.

The second, or longer range, part of solving the training problem was the initiation of an internal study program in the Fall of 1985 and completed in August 1986 to answer the

question: "How to best train personnel"? The study was limited to: the training requirements of the Process Engineers, (who man the consoles and make up the majority of the Launch Team) and the Managers and Test Directors (who must support decision making and crisis support). This limitation was imposed because the SPC had in place a very successful program to train and certify the technician work force. The system that evolved from the study of training for Firing Room personnel came to be called the Launch Team Training System (LTTTS).

The Launch Team Training System concept is not new. Airlines, the Department of Defense and the Nuclear Power Plant industry have been using simulator concepts in the training of their employees for a number of years. NASA has used simulator training in its astronaut program since the Mercury program. What is different from past simulation concepts is the number of people involved in training at one time, the number of parameters addressed, and the fidelity of the math models used.

The Study Team concentrated on identifying: the individuals and groups of people to be trained, the training requirements of each person or group identified, and the means to accomplish the training identified.

PEOPLE TO BE TRAINED

The following is an illustration of the scope of the training problem by showing a typical Launch Day Firing Room manning scheme.

There are 60 certified positions identified that make up the Firing Room Test and Launch Team.

Figure 2 illustrates personnel who control the Launch Countdown in the Prime Firing Room. There are approximately 175 Console Operator

Specialists in the front part of the Firing Room, 74 Computer Specialists in the back part of the Firing Room and 30 Test Management personnel in the upper part of the Firing Room.

Figure 3 illustrates the layout of the Engineering Support Areas used to support the Console Operator Specialists (Engineers) in the Prime Firing Room. There are approximately 211 highly experienced Systems Specialists and Managers located in these areas, comprised of representatives from the SPC, Rockwell, Martin, USBI, Rocketdyne, Morton Thicol, McDonnell Douglas and all their respective NASA counterparts.

The Complex Control Center, shown in Figure 4, is manned by 60 specialists in institutional systems such as facility power, air conditioning, pneumatics, water, etc.

As you can imagine, with this diverse set of personnel, the training requirements are diverse as well. The study indicated the following groups must be accommodated:

TEST MANAGERS - Contractor and NASA Test Conductors, Test Directors, Launch Directors, and Safety Directors.

TEST CONSOLE OPERATORS - Contractor and NASA Flight Hardware and GSE Process System Engineers representing 27 different technical disciplines.

COMPUTER OPERATORS - Computer operating and maintenance personnel.

FACILITY TEST SUPPORT OPERATORS - Contractor and NASA Facility & Support personnel representing 7 disciplines.

ENGINEERING SUPPORT PERSONNEL - Contractor and NASA specialists, including ISS and Payload. Decision making Managers who assist in troubleshooting and problem resolution.

The combined total of these groups comprises a combination of approximately 1,000 contractor and NASA personnel.

TRAINING REQUIREMENTS

The study indicated that the training methodology should be based on a building block arrangement. Figure 5 indicates the progression path a new Engineer should follow leading to certification and the maintenance of certification.

TRAINING MEANS

The existing simulation capability described earlier involves large numbers of personnel. The building block approach described above dictates that a single system and cluster simulation capability be developed to enable more intensive and focused training for an individual. Findings indicate the existing Countdown simulation time period should be extended to cover all 73 hours of a Countdown, and the model fidelity should be increased to the point where the console operator will not notice any significant difference between the modeled and real hardware.

The existing training system today provides qualified and certified personnel, the question is, "Can the mix of training media and emphasis be rearranged to make it more efficient and effective?"

FUTURE

KSC NASA and SPC management issued a Request For Proposals (RFP) to companies with expertise in the training and simulation fields to conduct a six month study of the NASA/SPC training process and equipment. The objectives of the study are to:

1. Make maximum use of existing methods, in-place systems, hardware and software as possible, but recommend whatever changes, innovations, or new equipment will be required to accomplish the overriding goal of providing quality training to the Test Team.

2. Recommend the proper mix of training methodologies to shorten training time of new personnel without sacrificing quality.

3. Provide the ability to maintain and improve the skill level of the existing Test & Launch Team.

4. Reduce training time using flight hardware.

5. Make provisions to allow the Team to experience and solve hardware malfunctions before encountering the real thing.

6. Provide the means to observe, manage and certify Teams and individuals, and maintain useful performance histories.

7. Recommend the means to introduce new training techniques and procedures without using flight hardware.

8. Recommend ways to overcome the existing limitations imposed on the simulation exercises by existing equipment and software.

9. Avoid negative training.

The SPC vision of the LTTTS of the future would include standardized training requirements for all console operations. By that, I don't mean everyone should spend the same exact hours training or take exactly the same courses, but should meet measured milestones of knowledge and skill levels required by their particular function. Management has an obligation to provide the proper tools to enable the trainees to

progress toward his goals in the most efficient manner, and become a productive member of the Team. Some of the "tools" might be workstations easily available to the employee in his own work area, where he can pursue self paced, interactive study programs of increasing complexity to learn his system. As the student progresses and becomes more familiar with his system, he could train and practice using his actual console, interacting with highly realistic models. He would receive immediate feedback on his performance from the program or a trainer. His training time and performance would automatically be recorded and made available to the student and the trainer for critique and analysis. Ideally, this part of the training process should be fun. Engineers should be standing in line to use these workstations and consoles.

The simulation system of this future LTTTS would be so flexible that changes to the actual hardware and software could be duplicated rapidly in the model programs to avoid negative training. The computer system would have a large enough mass storage and speed of operation to overcome the limitations of existing equipment. Some of the improvements envisioned are:

The rapid initialization, (within 10 minutes) of the total LPS/Simulation system. This would realize a saving of nearly the entire four hours it currently takes to do this job.

The ability to hold the Countdown at any point then proceed, reset, or backup to some predetermined point. It currently takes nearly 45 minutes to recycle back to a T-20 minute configuration. There is no existing capability to rapidly reset to a predetermined point other than T-9 minutes or T-20 minutes.

A feedback system to enable the simulation control engineers to monitor the execution of the models.

A menu driven malfunction selection capability to enable insertion of malfunctions in real time.

The automatic tracking of individual or teams training time and progress. Today training time and progress are tracked manually.

The ability to rapidly simulate manual operations such as cockpit switch positioning, hardware safing panels, or GSE valve actions to simulate responses to troubleshooting directions from System Engineers.

The ability to simulate (or utilize ground test hardware in place of models) for the Shuttle onboard general purpose computers, main engines computers and main engines. The ability to accommodate processing cycle transactions of less than 40 milliseconds with deviations from realtime of less than .25 seconds over less than 1 second durations.

Faster processing and increased capacity of the simulation computer to handle model sizes of approximately 900,000, 32 bit words, which would allow the additional capability to simulate major electrical bus failures, MDM bite test failures and realistic I/O errors presently not practicable.

The capability to accommodate several different single system simulations simultaneously as well as performance of cluster simulations in parallel with single system training.

In summary, refer to Table 1 for the plan to achieve the LTTS objectives.

The development of malfunction scenarios and the analysis required to understand and establish the correct response to the malfunction is

the first step in gathering the necessary knowledge to create expert systems. In the process of gathering this knowledge, we will have begun to accomplish one of the LTTS goals of knowledge transfer from the experienced "old hand" to the new "green" Engineer.

The three LTTS Study Contracts will be completed in June 1988. An SPC Team will evaluate the recommendations, consolidate requirements, and issue an RFP for implementation of the enhanced LTTS.

We believe the implementation of the LTTS will enable the NASA/SPC to sustain the skill depth of the experienced Launch Team as well as train and develop new Launch Team members. It will give us a very realistic tool to develop new techniques and procedures prior to use on the flight hardware. The LTTS will be able to expose an engineer to failures and allow him to train for correct responses, thus reducing the potential for human error on flight hardware. If, as a result of realistic simulations, we can save one 24 hour scrub turnaround, we will have saved the program approximately \$1,000,000. Most importantly it will begin the process of transferring the corporate knowledge and expertise of today's Launch Team to tomorrow's Launch Team trainees.

STS Turnaround Workday Comparison (As-Run Data)(1981-1984)

KSC/SO
19 August 1985

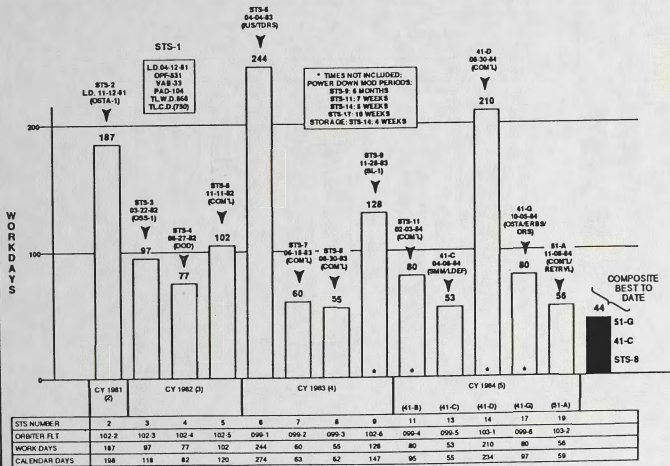


Figure 1

STS Turnaround Workday Comparison Plan (1985)

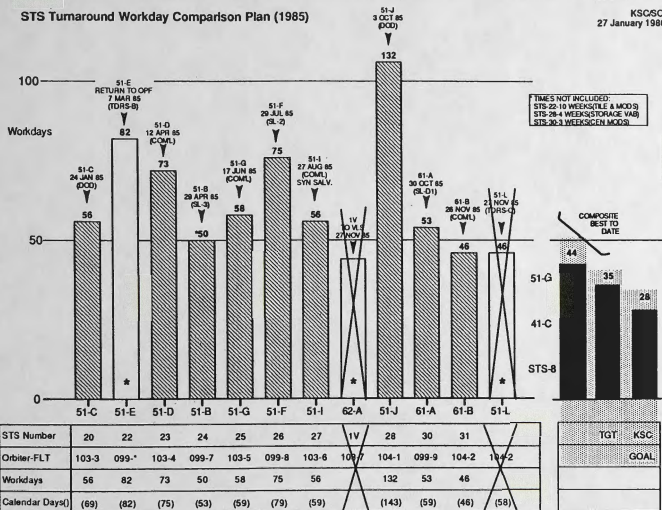
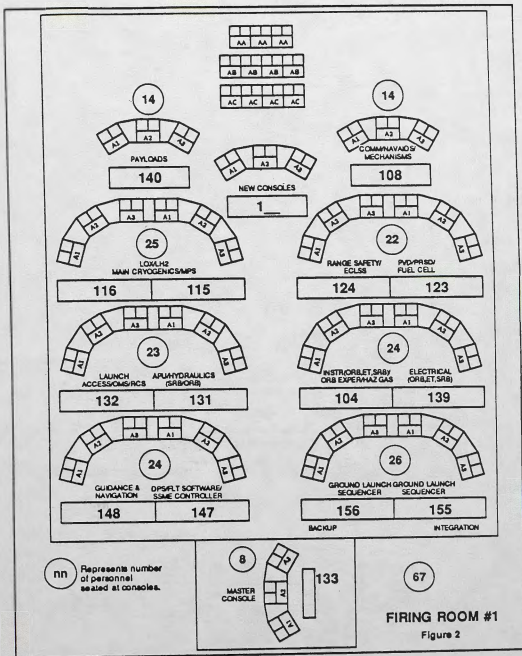
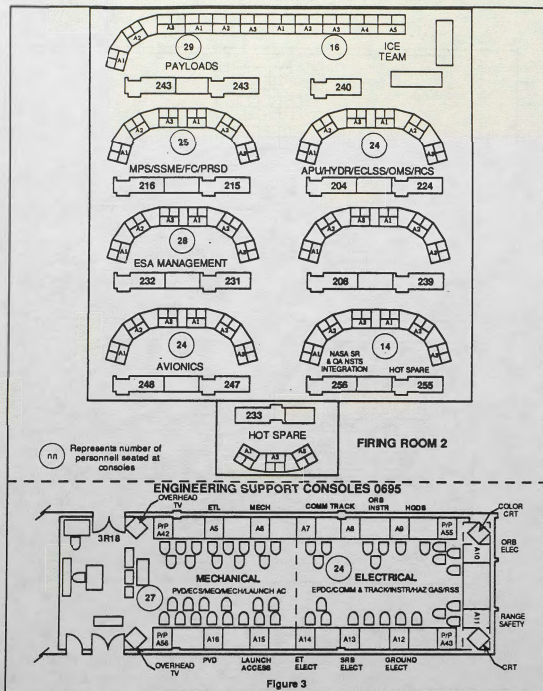
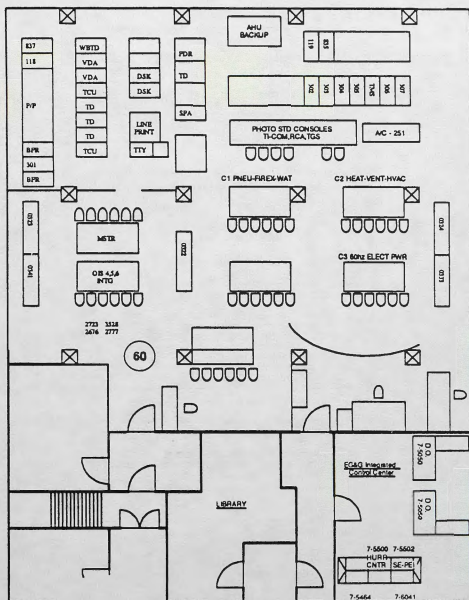
KSC/CSO
27 January 1986

Figure 1 (cont.)





CCC Room



nn Represents number of personnel seated at consoles

Figure 4

LTTS BUILDING BLOCK APPROACH

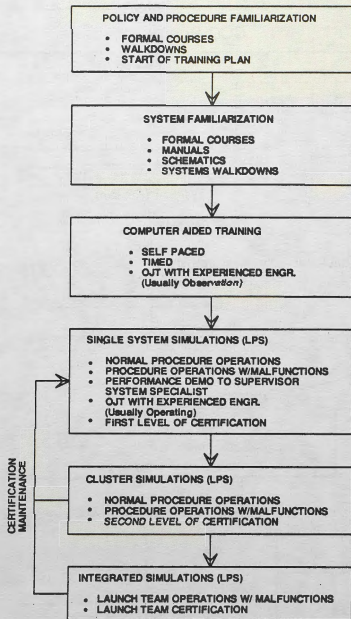


Figure 5

LTTS OBJECTIVES

REQUIREMENT	SOLUTION
1 Determine user groups	<ul style="list-style-type: none"> a. Test Managers b. Test Console Operators c. Computer Operators d. Facility Test Support Operators e. Engineering Support Personnel
2 Provide means to shorten training of new personnel without sacrificing quality.	<ul style="list-style-type: none"> a. Utilize existing formal courses. b. Establish computer aided programs - self directed and self paced. c. Expand existing simulation programs into Hi-fidelity single system, cluster, and fully integrated programs. d. Formalize and standardize the OJT training plans. e. Certify personnell after sucessfully participating in simulations and taking an oral exam.
3 Provide means to maintain and improve the skill level of the existing team members.	<ul style="list-style-type: none"> a. After certification - specify a minimum number of simulation exercises that must be completed in a given time period. b. Develop creditable failures to be inserted into the simulations and practice trouble shooting techniques and proper responses to emergencies.
4 Provide a means to introduce new techniques and procedures without using flight hardware.	<ul style="list-style-type: none"> a. Increase the fidelity of model programs so that there is virtually no difference between the model and the hardware.
5 Reduce training time using flight hardware.	<ul style="list-style-type: none"> a. By providing Hi-fidelity models and using real LPS consoles, the trainee will have experienced essentially the same operating environment as he would using actual hardware. Therefor, reruns or repeats of tests on real hardware caused by human error should be reduced.

LTTS OBJECTIVES

REQUIREMENT		SOLUTION
6	Provide a means to allow the team to experience and solve hardware failures before encountering the real thing.	a. This action will be accomplished if we properly answer 3, 4 and 5 above.
7	Provide a means to observe, manage and certify teams and individuals while maintaining useful performance history.	a. Each individual will be assigned a number and a planned training schedule. Unique number will be used to automatically track time spent on computer aided training and simulations. The student progresses through each milestone until he is certified. His training records will be kept and tracked for currency in the existing Training and Certification Record System (TCRS).
8	Make maximum use of existing hardware/software and training.	<p>a. Existing formal policy courses and systems courses taught by professional instructors will continue to be used.</p> <p>b. The existing TCRS System will be utilized.</p> <p>c. The CCMS LPS hardware and the existing applications software will be retained.</p> <p>d. Three contractors are currently studying the proper mix of existing training methods as well as existing hardware and operating software. The study is to be completed by June, 1988.</p>
9	Avoid negative training.	a. The operator will not know the difference between his real system and the model is the proper model control procedures are used and the fidelity of the model approaches the real hardware.